

# Measurements of the Fission Neutron Spectrum Using Threshold Activation Detectors Final Design

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**Theresa Cutler, John Bounds, Travis Grove, Dave Hayes, Jesson  
Hutchinson, Bill Myers, Rene Sanchez, Jessie Walker, Morgan White**

**Los Alamos National Laboratory**

# Overview of the Experiment

- **Purpose: Determine the prompt fission neutron spectrum (PFNS) of U-235**
  - The fidelity PFNS above 10 MeV is known to be questionable
- **Rocky Flats shells, with a hollow internal cavity**
  - ~93 wt. %  $^{235}\text{U}$
  - Shells 33-64
- **Use threshold activation detectors in a critical HEU system**
- **Designed on Planet critical assembly machine**



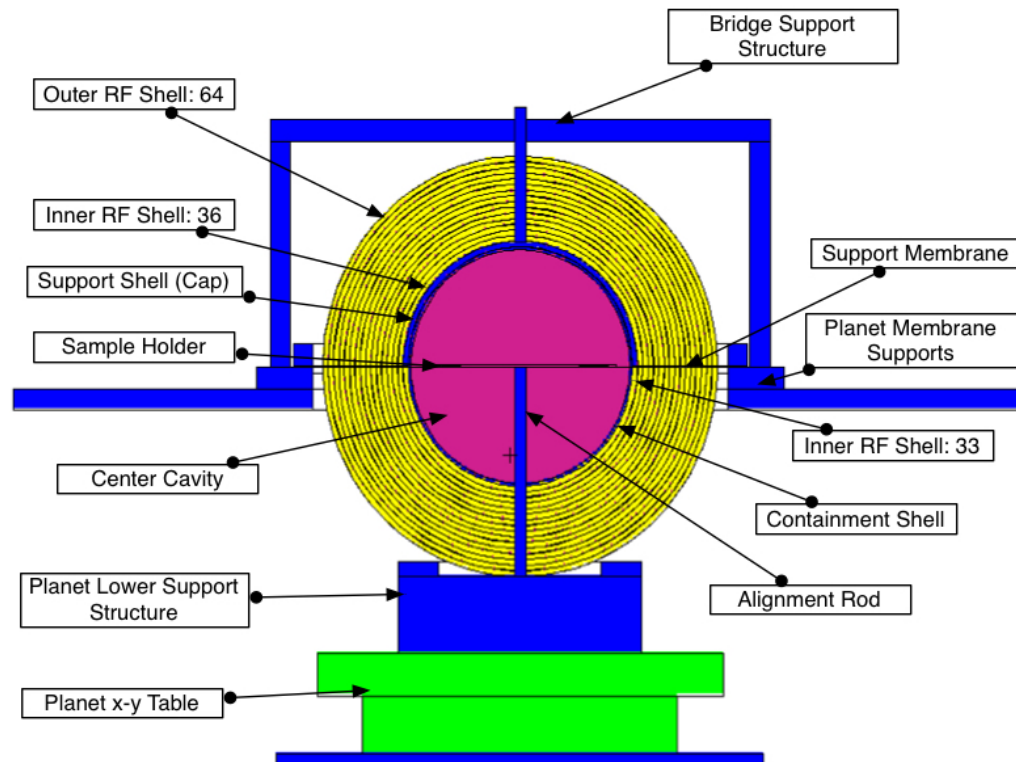
A photograph of a subset of the Rocky Flats Uranium shells

## Physical Characteristics of Rocky Flats Shells 33-64

<b>Average Thickness (cm)</b>	0.32
<b>Average Gap Thickness (cm)</b>	0.0098
<b>Average Density (g/cm<sup>3</sup>)</b>	18.65
<b>Shell 33 IR (cm)</b>	7.006
<b>Shell 64 OR (cm)</b>	12.336
<b>Total Mass of HEU Shells (kg)</b>	114.3
<b>Mass of HEU shells above Support Membrane (kg)</b>	54.15

# Overview of Model

- Simulations performed in MCNP6® using ENDF/B-VII cross sections

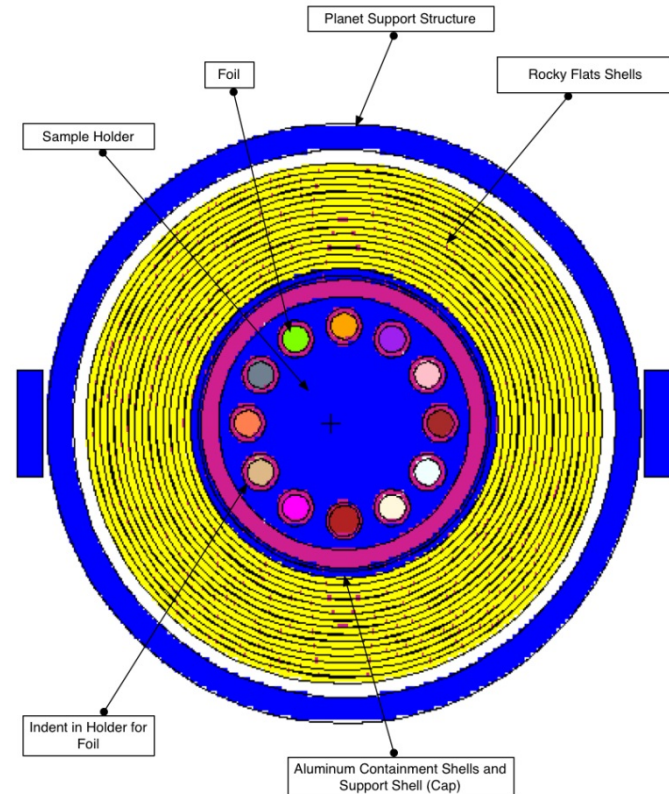


Blue=Aluminum, Green=Steel, Yellow= Uranium, Pink=Air.

# The Sample Holder

<b>Plate Radius</b>	6.00
<b>Plate Thickness</b>	0.15875
<b>Indent Depth</b>	0.0375
<b>Radius to Center of Indents</b>	0.4611
<b>Indent Radius</b>	0.889
<b>Foil Radius</b>	0.635
<b>Alignment Rod Radius</b>	0.357

Dimensions in cm



# Description of MCNP6<sup>®</sup> Simulations

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- **ENDF/B-VII cross sections**
- **Foils modeled as pure samples with naturally occurring isotopic distributions**
  - Based on previous examination of foils from Shieldwerx
- **Composition of Rocky Flats Shells and Planet structure come from ICSBEP benchmarks**
  - Density of Rocky Flats shells conserve mass which is necessary because the lateral holes were neglected
  - Consistent with other reports
- **Includes 11 of the candidate foil materials which cover the full energy range of interest**
- **Reaction rate tallies segmented into 130 discrete energy bins, spanning 0 to 21 MeV**
  - Aim to find mean neutron interaction energy ( $E_{50}$ )
- **$K_{eff}=1.00833 \pm 0.00003$**

# Foil Materials and Activation Reactions

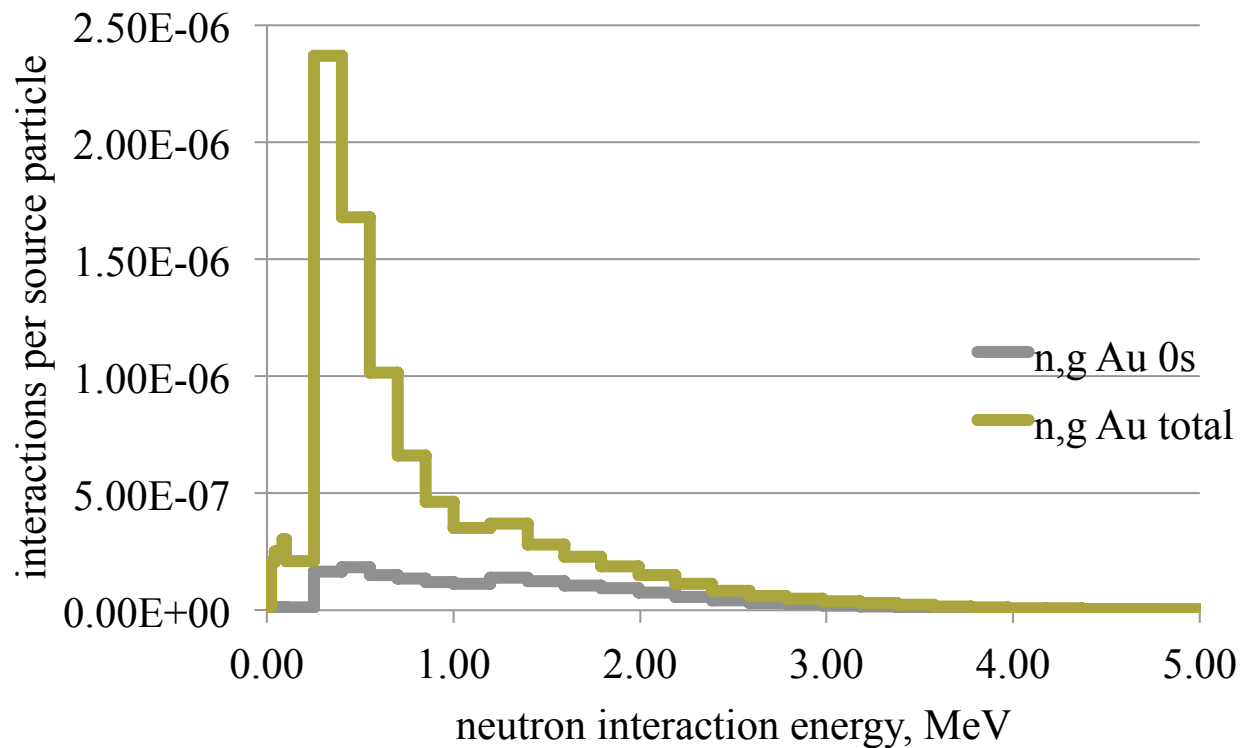
Foil Material	Foil thickness, mil	Isotope of Interest	% Natural Abundance of Isotope of Interest	Reaction	Cross Section, [b]	E_50 [MeV]	Nucleus	Half-life
DU	5	238U	99	238U(n,f)FP	0.31539	2.73	/	/
Iron	5	54Fe	5.85	54Fe(n,p)54Mn	0.08692	4.23	54Mn	2.58 h
Nickel	10	58Ni	68.0769	58Ni(n,p)58Co	0.118	3.94	58Co	2.73 y
Copper	10	63Cu	69.17	63Cu(n,a)60Co	0.000689	7.24	60Co	9.67 m
	10	65Cu	69.17	65Cu(n,2n)64Cu	0.000689	12.64	64Cu	14.9 h
Aluminum	10	27Al	100	27Al(n,a)24Na	0.001017	8.40	24Na	9.462 m
Gold	1	197Au	100	197Au(n,γ)198Au	0.078	0.75	198Au	9.6 h
Gold with 4 mil Cd cover	1	197Au	100	197Au(n,γ)198Au	0.078	0.75	198Au	9.6 h
	1	197Au	100	197Au(n,2n)196Au	0.00051	10.61	196Au	12.7 h
Cobalt	2	59Co	100	59Co(n,α)56Mn	0.000222	8.36	56Mn	70.86 d
Vanadium	2	51V	99.75	51V(n,p)51Ti	0.000649	6.44	51Ti	43.67 h
	2	51V	99.75	51V(n,α)48Sc	0.000039	9.10	48Sc	14.9 h
Magnesium	5	24Mg	78.99	24Mg(n,p)24Na	0.002	8.25	24Na	13.11 h
Zirconium	5	90Zr	51.45	90Zr(n,2n)89Zr	0.000221	14.41	89Zr	249 d
Titanium	5	46Ti	8.25	46Ti(n,p)46Sc	0.01409	5.90	46Sc	83.7 d

# Foil Selection

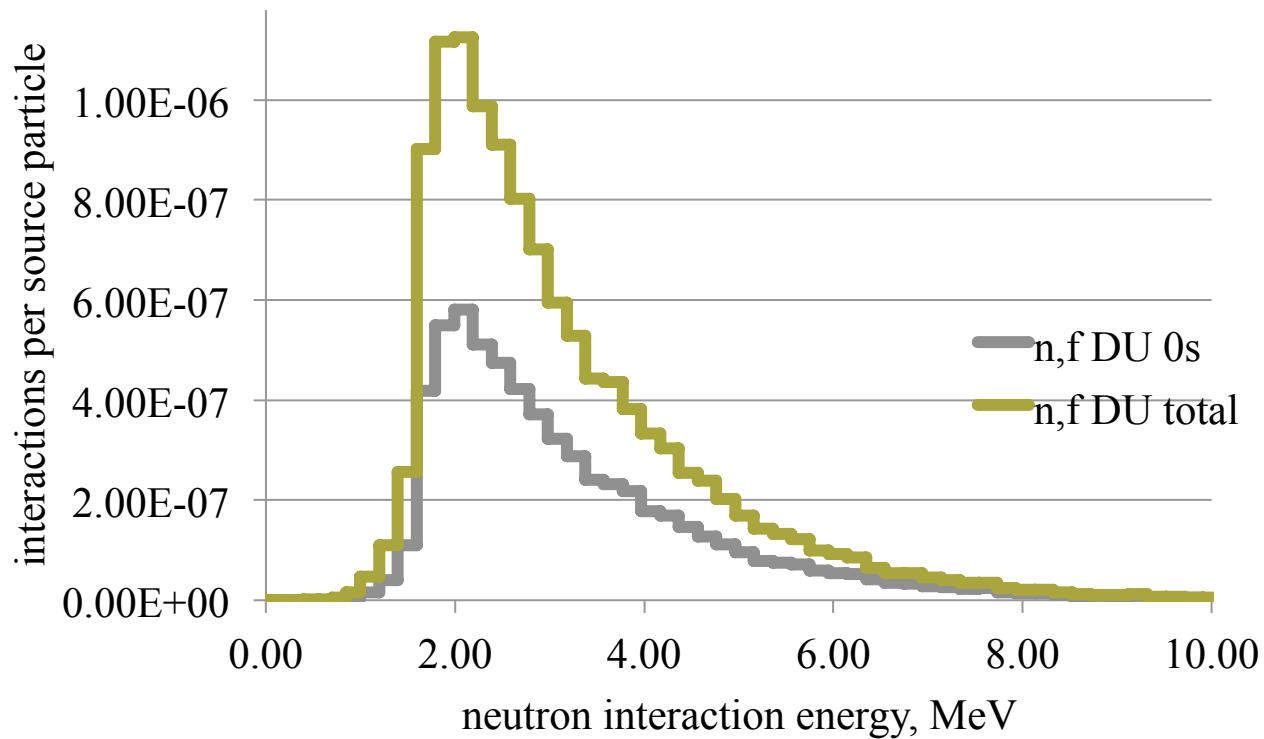
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- All reactions come from [International Reactor Dosimetry and Fusion File \(IRDFF\) v.1.03](#) Cf-252 Spontaneous Fission Library
- Prior experience with reaction rate foils
- Shieldwerx Catalog
- Full Energy Spectrum with Mean Interaction Energy up to 13 MeV
  - Thermal/epithermal range
  - High energy range
- Considered effects of competing n, $\gamma$  low energy interactions
- Percent of interactions from unscattered neutrons
- High energy interactions primarily (n,2n); (n,p); (n, $\alpha$ )

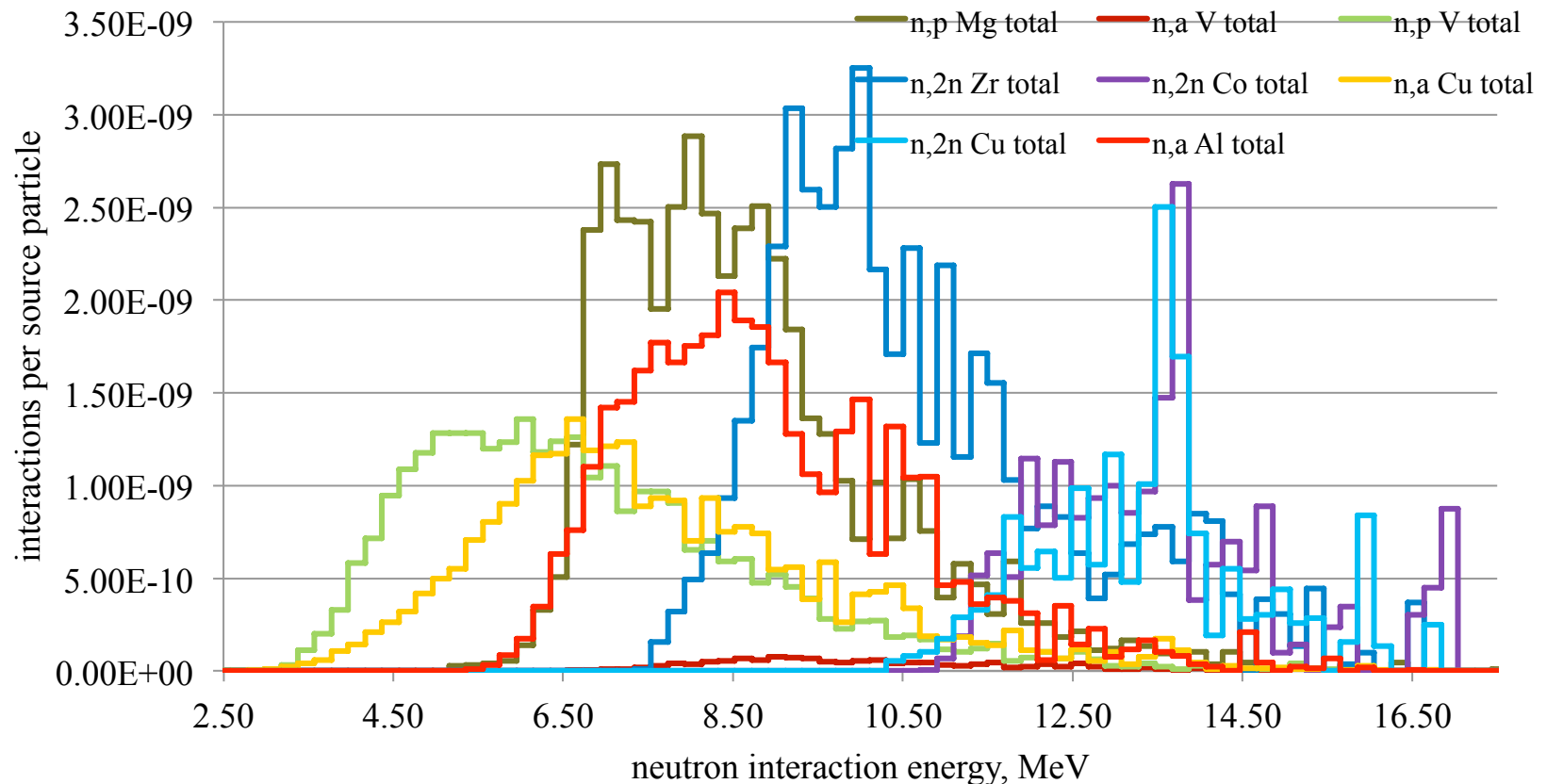
# Gold Relative Reaction Rate



# DU Relative Reaction Rate



# Threshold Reactions



# Post-Experiment Analysis

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## ■ Initial Counting of Reactions

- Use well shielded HPGe to measure gamma peaks associated with the threshold reactions of interest
- Each foil counted separately
- Time after irradiation based on dose rates and total reactions needed for reasonable statistics

## ■ Spectrum Unfolding

- Use EASY-2A and FISPACT-II
  - European Reactor Codes

# CEDT Process

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- **CED-2 approved September 2014**
- **Currently in CED-3a**
  - Final configuration established
  - All structural pieces have been designed and ordered
  - Final Foil selection is nearing completion
    - All will be bought from Shieldwerx
  - Scheduled to proceed to CED-3b in October 2016

## **IER 153: Measure the Fission Neutron Spectrum Shape Using Threshold Activation Detectors. CEDT Phase-2 Detailed Design**

**Requestor:** Morgan White<sup>1</sup>

**Supporting Authors:** Theresa Cutler, Travis Grove, William Myers, Rene Sanchez<sup>2</sup>

**Affiliation:** Los Alamos National Laboratory

**Executive Summary:** The objective of integral experiment request (IER) 153 is to determine the prompt fission neutron spectrum (PFNS) of the uranium isotope  $^{235}\text{U}$ . To meet this objective, activation foils will be placed in a central void region of a critical configuration consisting of concentric highly enriched uranium (HEU) metal shells. The set of activation foils will exercise various regions of the fission spectrum, thereby giving ratios of neutrons emitted across the full PFNS.

# Thank you

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